Deposition and Remobilization of Multiwalled Carbon Nanotubes on Silica Surfaces: Implications for Environmental Fate and Transport

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Carbon nanotubes (CNTs) are increasingly used in commercial and industrial applications because of their unique physical, mechanical, and electronic properties. With the escalating growth in the production of consumer products containing CNTs, it is inevitable that some of the nanotubes will be released into natural and engineered aquatic systems. Thus, in order to predict the fate and transport of CNTs in surface water and groundwater systems, it is important to understand the interaction between CNTs and natural surfaces. The objective of this study is to investigate the influence of solution composition on the deposition kinetics and degree of remobilization of oxidized multiwalled carbon nanotubes (MWNTs) on silica surfaces. The distributions of oxygen-containing surface functional groups for two MWNTs are determined using X-ray photoelectron spectroscopy in conjunction with vapor phase chemical derivatization. The deposition kinetics of lowly oxidized MWNTs (LO-MWNTs) and highly oxidized MWNTs (HO-MWNTs) are compared in monovalent (NaCl) and divalent ($CaCl_2$) electrolytes using a quartz crystal microbalance with dissipation monitoring (QCM-D). HO-MWNTs are found to be more stable to deposition than LO-MWNTs in the presence of NaCl. However, the attachment efficiency profiles of both MWNTs are observed to be comparable in the presence of $CaCl_2$. This similarity is possibly due to Ca^{2+} cations having a higher affinity to form complexes with adjacent carboxyl groups on HO-MWNTs than with isolated carboxyl groups on LO-MWNTs. Our results also show that some of the deposited MWNTs can be released from silica surfaces when they are rinsed with low ionic strength solutions. The degree of nanotube release is found to be dependent on the ionic strength and pH of rinsing solutions.